

SPHERES

Synchronized, Position, Hold, Engage, Reorient,
Experimental Satellites



SPHERES/Astrobee Working Group (SAWG) Quarterly Meeting

July 22, 2019





Agenda

SPHERES/Astrobee Working Group			Location: NASA KSC				
Draft, Subject to change							
Date:	July 22nd, 2019, 9am EST	In-Person, NASA Kennedy Space Center, M7-355 O&C					
Agenda	Group	Project	Name	Time	duration (min)	In-Person?	Attendance
0	NASA Ames	Introductions	Jose Benavides	9:00 AM	0:10	1	
1	NASA HQ	AES Program Welcome	Andres Martinez	9:10 AM	0:05	0	
2	NASA Astrobee	SPHERES Facility Status	Jose Benavides	9:15 AM	0:20		
3	NASA ISS	SPHERES PIM Status	Melissa Boyer	9:35 AM	0:10	0	Yes
4	NASA Astrobee	Astrobee Status	Maria Bualat	9:45 AM	0:20	1	
5	NASA ISS	Astrobee PIM Status	Larry Cotton/Tyler	10:05 AM	0:15	0	Yes
6	NASA ISS TDO	NASA ISS Program TDO overview	Dave Hornyak/Henry	10:20 AM	0:05	0	Yes
7	CASIS	ISS National Lab Overview	TBD	10:25 AM	0:05	0	?
8	Instituto Superior Técnico	Progress towards object manipulation by free-flyer robots in microgravity	Rodrigo Ventura	10:30 AM	0:20		yes
9	Break			10:50 AM	0:15		
10	MIT	SPHERES ReSwarm, Zero Robotics	Alvar Otero/Richard Linares	11:05 AM	0:20	2	
11	Lunch			11:25 AM	1:00		
12	NASA Logistics	RFID Recon	Andrew Chu	12:25 PM	0:20	0	Yes
13	Astrobotic/Bosch	Sound See	Andrew Horchler	12:45 PM	0:20	0	?
14	Stanford	Gecko-Inspired Adhesive Appendages for Automated Logistics	Abhi/Tony/Arul/Dr. Bylard	1:05 PM	0:20	4	
15	FIT	RINGS/SVGS	Hector Gutierrez	1:25 PM	0:20	1	
16	Tethers Unlimited	AstroPorter	Nathan Britton	1:45 PM	0:20	1	
17	Break			2:05 PM	0:15		
18	NPS	Astrobatatics	LT Jonathan Chitwood	2:20 PM	0:20	1	
19	Columbia	Versatile Manipulation for Assistive Free-Flyers	Matei Ciocarlie	2:40 PM	0:20		
20	TBD			3:00 PM	0:20	1	
22	NASA Ames	Wrapup, Action Items	Jose Benavides	3:20 PM	0:15	1	
23		Depart		3:35 PM	0:10		



SPHERES Community

□ SPHERES Working Group (SWG) Quarterly meeting

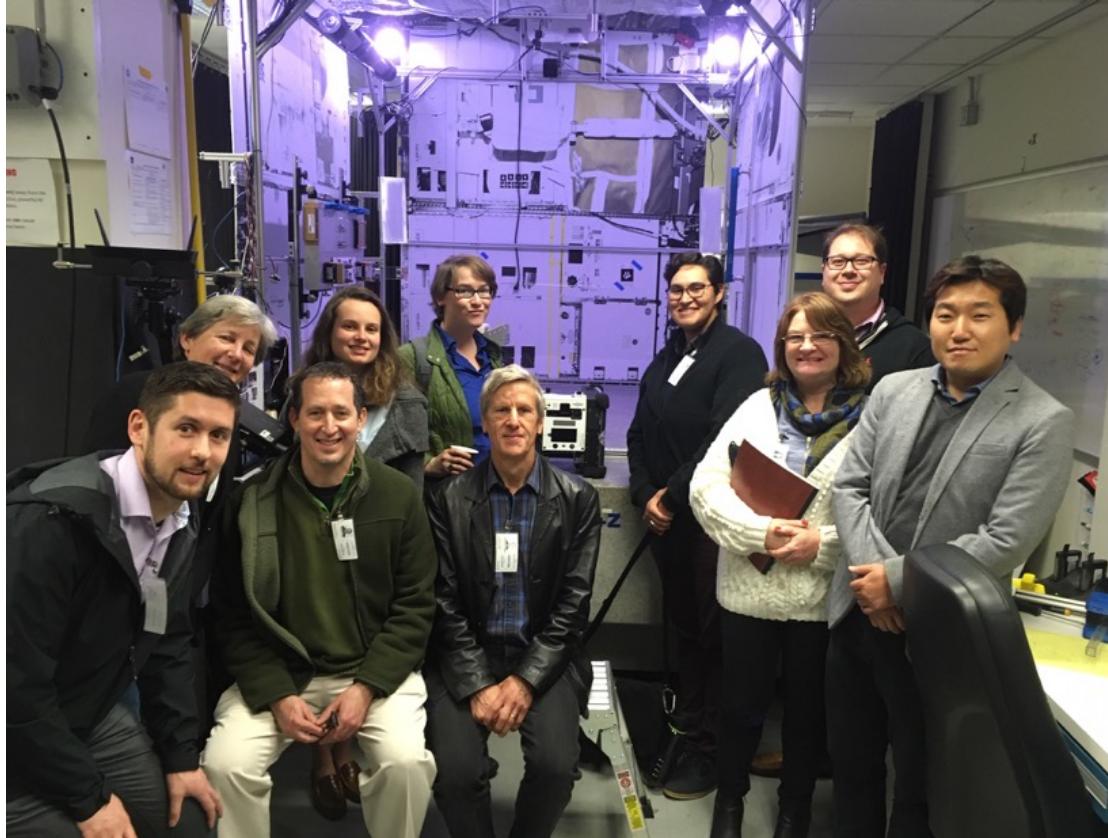
- Membership includes MIT, FIT, AFS, DARPA, CASIS, Airbus, and NASA (HQ, KSC, JSC, MSFC, and ARC)
- Face-to-Face, twice a year
- Next will be scheduled on March 2019, location: Telecon

□ Purpose:

- Information sharing across the SPHERES/Astrobee community
 - Astrobee Facility shares
 - ✓ National Lab Facility availability
 - ✓ Status of resources (batteries, CO2 tanks, etc.),
 - ✓ Overall Calendar (scheduled Test Sessions, upmass/return), and
 - ✓ Updates on “new” PD, Investigations, and ISS infrastructure.
 - Provide the SPHERES/Astrobee community (PD, investigators, etc.) with up-to-date information to determine opportunities to use the NL Facility
 - Discuss proposed changes/updates to Astrobee Nat Lab which may be required to support a specific activity or research.
 - Discuss specific support requests made to the ISS Office
-



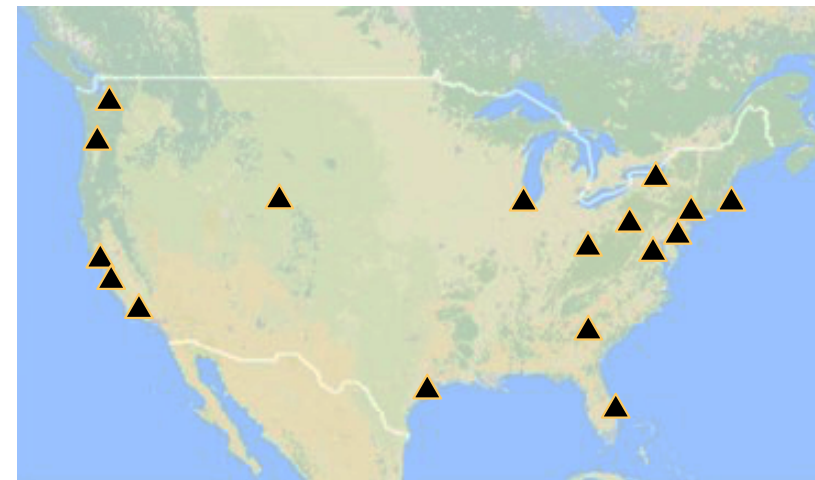
SPHERES Community





Guest Scientists

- ❑ Replacing SPHERES, it is anticipated that Astrobees will carry on as the **most highly utilized payload** on the ISS
- ❑ 7 Projects actively working towards ISS payloads
 - Zero Robotics (MIT)
 - Astrobatics (Naval Postgraduate School)
 - SoundSee (Astrobotic/Bosch)
 - Gecko (Stanford)
 - RFID Recon (NASA REALM)
 - JAXA joint activity
 - [Port Tester]



Astrobees guest scientist institutions in the US

- ❑ **Ground Studies**
 - FIT/RINGS
 - Tethers Unlimited
 - NK Labs
 - NMSU



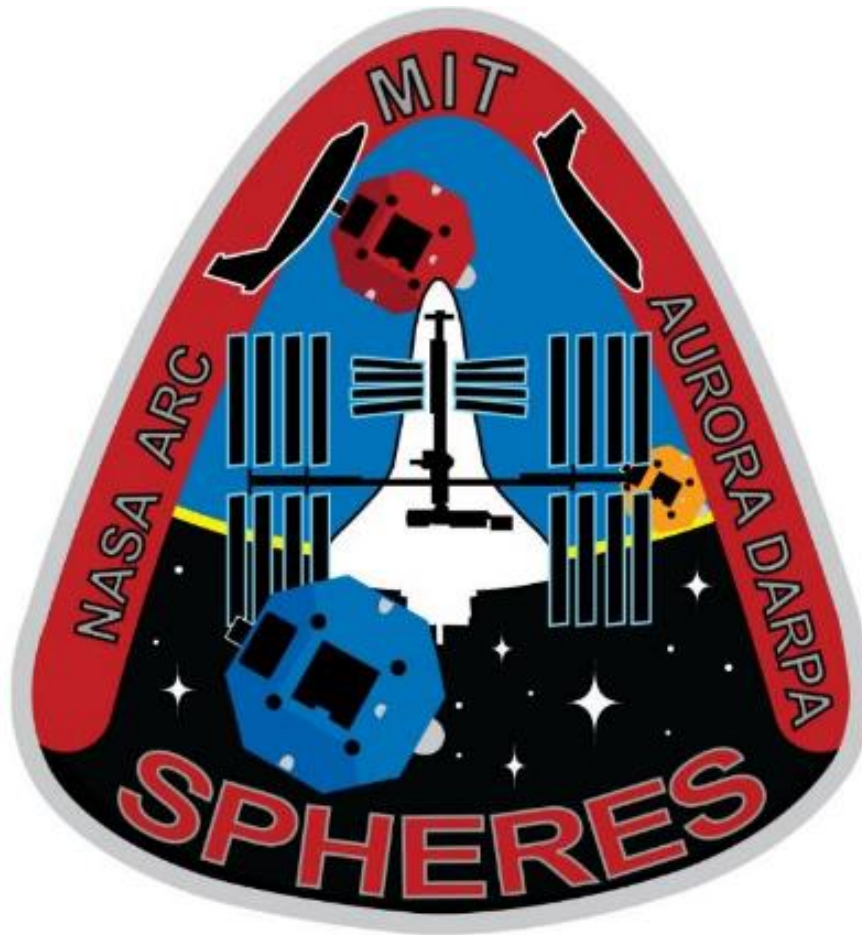
Highlights

□ TBD



What's next ...

□ TBD

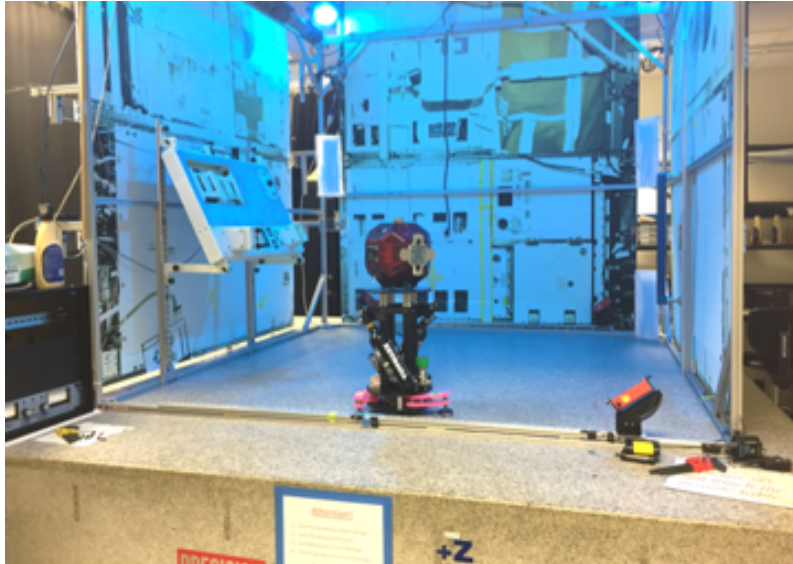


SPHERES Engineering



Ground Lab Status

- Granite Lab: Online



- Flight Lab: Online



- Micro Gravity Test Facility (MGTF) Lab



- Engineering Evaluation Lab (EEL): Available upon request



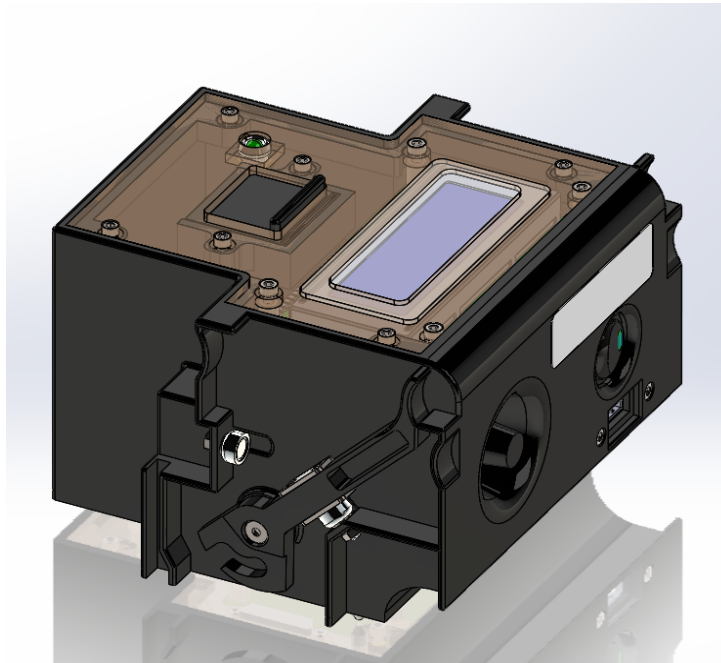
Hardware Status (Astrobee)

Name	Status	Plans
P4E	Operational	Dev. Testing in MGTF
Flat Sat A	Operational	In use by FSW team
Flight 1,2	Complete	In Space
Flight 3	Complete	Launched?
Flight Spare	Complete	At JSC for integrated testing (EMI, Acoustic)
Cert (B#)	Operational	In use by FSW team
Ground (Melissa)	Operational	In use by FSW team



Port Tester

- ❑ Facilitate diagnostics of the Astrobee Free Flyers' internal USB ports and USB pass-through connection to the HLP
- ❑ Test safe electrical current and voltage operation limits
- ❑ Serve as an internal ARC based payload to learn and better improve the guest science payload development process





Port Tester Updates

- ☐ Completed PSRP Phase III (passed with comments)
- ☐ Completed EMI testing with SoundSee (07/15-07/18)
- ☐ Building flight units for on dock (08/06)



SPHERES & Astrobee Operations



Operations: Functions

Ensure Facility Readiness for ISS Test Sessions

- All crew training now via Onboard Training (OBT) both English & Russian
- Crew procedure updates
- Coordinate with ISS Lead Increment Scientist and POIC Cadre
- Flight products on orbit (test plan, .spf, on-board training and review, etc.)
- Consumables (CO2 Tanks and Batteries) refurbishment and resupply
- Support SPHERES directory/file maintenance

Real-Time ISS Test Session support

- Coordinate with investigators for product development and delivery
- Support crew & POIC cadre real-time Ops – conduct crew conferences as needed
- Help investigators set up remote comm. capabilities as needed
- Test session data and video management

Public Relations

- Maintain website, work with ARC PAO office to publish material on site



Operations: Functions

Increment Planning

- PTP and 2-pager development, and update & support and submittal
- Timeline planning model review and update

Safety and Verification Assessments

- Integrated Safety & Verification Assessments for all SPHERES payloads
- Safety & Verification assessments for Battery/Tank launches/returns
- Complete Certification of Flight Readiness for ground systems and on-orbit hardware and operations products
- Conduct ISS Requirements Change Assessments to SPHERES Facility

Astrobee Ground Ops Development

- On orbit Activity planning and development
- Ground Operations & Engineering Readiness Test planning/development
- OBT (Onboard Training) videos [headed up by DW – complete to date!]



Increments 59/60

- **SPHERES Test Sessions (since last SWG 3.20.19)**
 - **SmoothNav Science 4 Data Retrieval – May 20**
 - Unfortunately, the data was not properly downloaded, other plans are being discussed how to get the data (additional retrieval sessions, HW return...)
- **Astrobee Commissioning Activities (since last SWG 3.20.19)**
 - **Astrobee A (Bumble) Checkout – April 30, 2019**
 - **Astrobee A Mapping & Calibration – May 13, 2019**
 - **Astrobee A Mapping & Calibration Repeat – May 23, 2019**
 - **Astrobee A Localization & Mapping 1 – June 14, 2019**
 - **Astrobee A Localization & Mapping 2 – July 12, 2019**
- **Astrobee Ops Planning for Increment 60**
 - **Procedures and planning products developed for the following:**
 - **Astrobee B (Honey) Checkout & Calibration**
 - **Crew Interface**
 - **Ops Demo**



Increments 60 Look Ahead

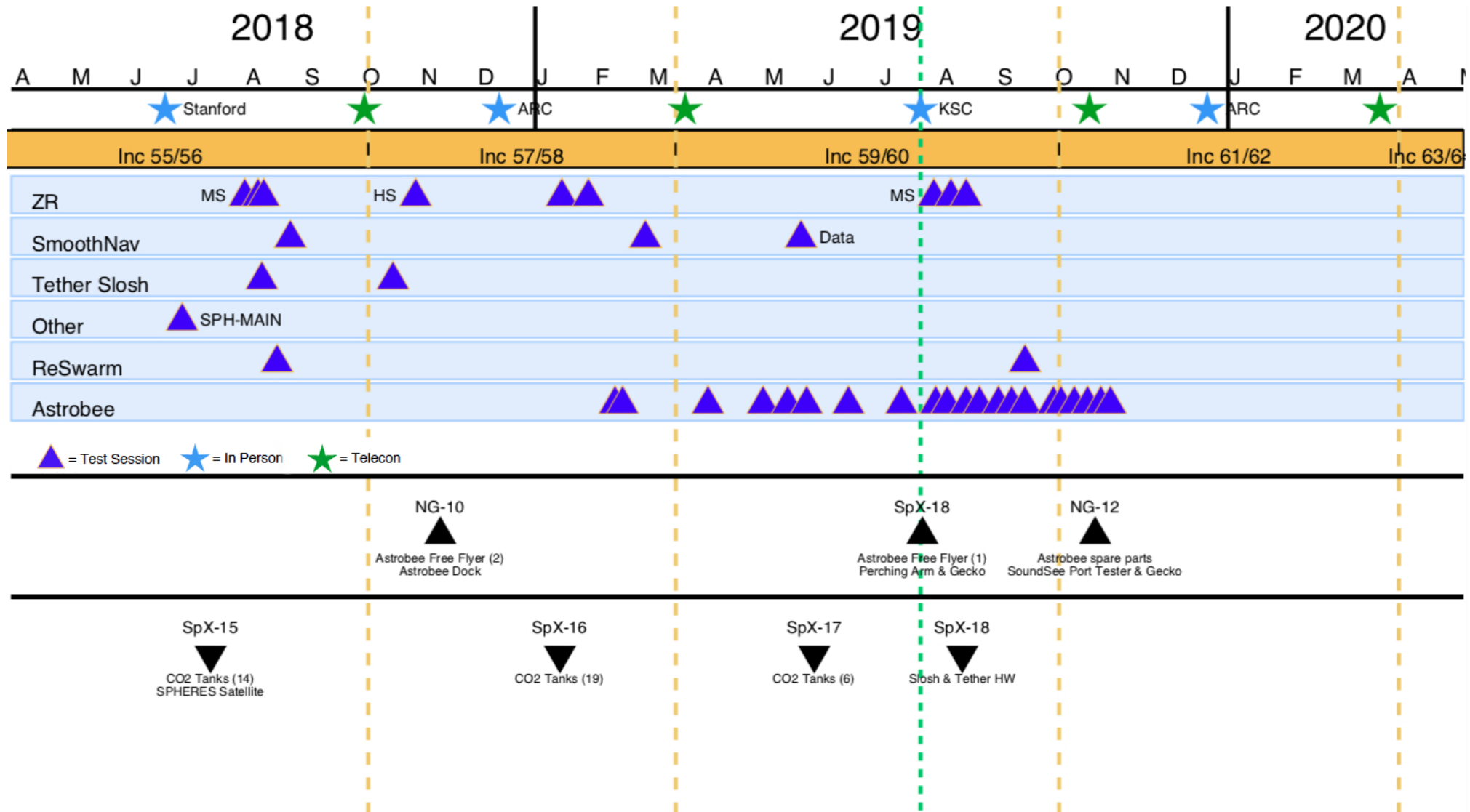
#	Event/Activity/Task/Session Description	Template Date(s) & Flexibility
1	Dock Software Update	4/1/2019
2	Astrobee A Checkout	4/30/2019
3	Astrobee A Calibration & Mapping	5/13/2019
4	Astrobee Mapping 2	5/23/2019
5	Astrobee A Localization/Mobility 1	6/14/2019
6	Astrobee A Localization/Mobility 2	7/12/2019
7	Astrobee A Localization/Mobility 3	TBD (end July-early August)
8	Astrobee B Checkout/Calibration	TBD (end July-early August)
9	Astrobee B Localization/Mobility 1	TBD (August)
10	Astrobee B Localization/Mobility 2	TBD (August-September)
11	Ops Demo	TBD (August-September)
12	Crew Interface	TBD (September)
13	Payload Install (Perching Arm)	TBD (September)
14	Astrobee C Checkout/Calibration	TBD (September-October)
15	Performance Characterization 1	TBD (October+)
16	Performance Characterization 2	TBD (October+)
17	Astrobee C Localization/Mobility 1	TBD (October+)
18	Astrobee C Localization/Mobility 2	TBD (October+)
19	SPHERES/Astrobee Hand-off	TBD (October+)

SPHERES

- ☐ Zero Robotics Middle School Units Test
 - July 30, 2019
- ☐ Zero Robotics Middle School Dry Run
 - August 7, 2019
- ☐ Zero Robotics Middle School Finals
 - August, 9 2019
- ☐ ReSwarm Science 2
 - TBD August - September 2019



SPHERES & Astrobees Calendar





Safety-Verification & Consumables

Safety

- SPHERES CO2 Tanks (empty) Return on SpX-17 – Approved: 5/24/2019

Verification

- SPHERES Software Update – Under review

CO2 Tank Inventory

- 45 Tanks (1 gray, 44 pink) on orbit – **will support remaining sessions**

Battery Pack Inventory

- 15 Batteries on orbit - **should support remaining sessions**
- 10 SPHERES Rechargeable Batteries – checked out and used several times

Consumables downmass

- 6 empty gray tanks returned on SpX-17
- Planning to return empty gray and pink tanks



SPHERES & Astrobee on Social Media

Twitter

https://twitter.com/NASA_SPHERES

Website

<http://www.nasa.gov/spheres>

<http://www.nasa.gov/astrobee>

SPHERES

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Related Topics

NASA Ames
Living in Space

Tether Slosh

Over a year after the first SPHERES Tether Demonstration Test Session was conducted on the International Space Station (ISS), researchers are aiming to expand their knowledge of tethering to captured objects and "space tug" chase vehicles in microgravity. In December 2017, a new investigation, called "Tether Slosh," launched new hardware to the ISS on SpaceX-13 that will integrate with existing SPHERES, Tether, and Slosh hardware on the ISS. Compared to the Tether Demonstration, the Tether Slosh Investigation has added new mechanical features that will be tested with new sophisticated algorithms and modeling techniques for liquid sloshing in space vehicles. Two SPHERES satellites will be used to represent the capturing vehicles pulling a liquid tank inside the ISS Japanese Experiment Module to study the sloshing effects and better understand its fluid dynamics in microgravity.

What is SPHERES?

SPHERES consist of 3 free flying satellites on board the International Space Station that test a diverse range of hardware and software from scientist all over America. SPHERES has been active for 10 years and continues to be one of the most popular NASA projects and a favorite of many astronauts who are fortunate enough to work with the SPHERES project.

SPHERES Zero Robotics High School 2016

On Wednesday January 4, 2017, the SPHERES Zero Robotics (ZR) Units Test session was performed on the International Space Station (ISS). This is the first of three ZR sessions for this month. The third session, planned for January 27, is a finale event in which teams of students will see their code run live on the SPHERES satellite on the ISS.

SPHERES Shatters Own Record For Highest Operating Tempo in

SPHERES Tether Demonstrates

Tweets by @NASA_SPHERES

Astrobee Status



SPHERES-Astrobee Working Group

July 22, 2019



Hardware Status

Honey	Bumble	Queen
Stowed	Operational	Stowed

- Docking Station
 - Launched on NG-10 – 11/17/18
 - Installed on 2/15/19
- 2 Astrobees (Bumble & Honey) and Dock Spares Kit
 - Launched on NG-11 – 4/17/19
 - Checkout of Bumble began 4/30/19
 - Checkout of Honey around 7/25/19
- 1 Astrobee (Queen) and 3 Perching Arms
 - Launching on SpX-18 – 7/21/19
 - All hardware delivered and verifications closed
- Astrobee Spares Kit and Port Tester
 - Launching on NG-12 – 10/19/19
 - On-dock 8/6/19



Astrobee Commissioning Activities

1. Checkout
 - Crew inspects the robot
 - Functional tests of all hardware
2. Calibration & Mapping
 - Crew collects camera and IMU calibration data
 - Crew collects mapping data of Kibo
3. Localization & Mobility
 - Verify robot localization within Kibo
 - Robot performs increasingly complex motions to test mobility system
4. Checkout & Calibration
 - Combination of 1 & 2 without mapping
5. Crew Interface
 - Crew controls an Astrobee using the Crew Control Station on an EXPRESS laptop



Astrobee Commissioning Activities

6. Ops Demo

- Demonstrate an operational mission scenario

7. Payload Installation

- Crew installs payload (perching arm)
- Functional tests of payload

8. Payload Demo

- Operational demonstration of payload (perching arm)

9. Performance Characterization

- TBD tests to further characterize Astrobee performance

10. SPHERES/Astrobee Hand-off

- Symbolic passing of the torch from SPHERES to Astrobee
- Completion of commissioning



Commissioning Schedule

Completed | **Scheduled** | Desired

Activity	Robot	Date
Checkout	Bumble	4/30/19
Calibration & Mapping	Bumble	5/13/19
Additional Mapping	Bumble	5/23/19
Localization & Mobility	Bumble	6/14/19
Localization & Mobility	Bumble	7/12/19
Checkout & Calibration	Honey	7/29/19
Localization & Mobility	Bumble	8/1/19
Localization & Mobility	Honey	8/13/19
Checkout & Calibration	Queen	8/20/19
Localization & Mobility	Honey	8/27/19



Commissioning Schedule

Completed | Scheduled | Desired

Activity	Robot	Date
Ops Demo	TBD	9/10/19
Crew Interface	TBD	9/17/19
Payload Installation	TBD	9/20/19
Payload Demo	TBD	9/24/19
Localization & Mobility	Queen	10/1/19
Localization & Mobility	Queen	10/8/19
Performance Characterization	TBD	10/15/19
Performance Characterization	TBD	10/22/19
SPHERES/Astrobee Hand-off	TBD	10/29/19

Note: This is an extremely aggressive schedule. We anticipate some slips, especially later in the campaign.



Bumble Checkout





IMU Calibration





1st Flight





Stopping Ability





1st Autonomous Undocking





1st Autonomous Docking





Fun with Robots



Questions?

